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ABSTRACT

A Study was conducted to test the hypothesis proposed by J. S. Symmes and J. L. Rapoport that a sex-linked recessive gene might account for the good spatial ability found among dyslexic readers, the familial pattern of the disorder, and the frequently reported sex ratio of three affected males to one female. Spatial/reasoning ability scores were obtained from 125 dyslexic children, their biological parents, their siblings, and 125 matched control families. The results indicated that although males tended to perform better than females on tasks requiring spatial/reasoning ability, there was no reason to believe that ascertainment bias favoring dyslexic males with superior spatial ability could account for the 3:1 sex ratio. Tests for sex linkage also failed to confirm the Symmes-Rapoport hypothesis. With regard to familial patterns of spatial ability, spatial/reasoning scores obtained from biological siblings and parents of the dyslexic children confirmed a familial pattern of competence but not of superiority when compared to the respective members of the control families. Thus, a familial pattern of reading deficits did not appear to be etiologically related to spatial/reasoning ability. (FL)

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Spatial Ability in Relatives of Reading-Disabled Children

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ABSTRACT

Spatial/reasoning scores were obtained from 125 reading-disabled children, their biological parents and siblings, and from 125 matched control families (total N = 1044). Results from this study indicate that the 3:1 sex ratio of affected males to females is not related to ascertainment bias favoring reading-disabled boys with superior spatial ability, nor is it related to a recessive sex-linked major gene which codes for superior spatial ability. Rather, there was evidence for a familial pattern of spatial/reasoning competence which stands in marked contrast to the familial pattern of reading deficits reported previously.

INTRODUCTION

Several investigators* have considered the possibility that a hereditary form of reading disability may be characterized by adequate to superior spatial ability. For example, Gordon (1980) found that the siblings and parents of 11 dyslexic children demonstrated a cognitive profile that was characterized by better scores on spatial or performance tests thought to measure right hemisphere function, than on sequential or verbal tests thought to measure left hemisphere function. Because evidence exists that both reading disability and spatial visualization may be influenced by genetic factors (see Finucci, 1978; Vandenberg and Kuse, 1979), Gordon concluded that such a cognitive pattern might be typical of a hereditary form of reading disability.

A more specific genetic hypothesis has been suggested by Symmes and Rapoport (1972). They reasoned that if, as Stafford (1961) has proposed, male superiority in spatial visualization is due to sex-linked recessive inheritance, then reading disability might be linked to a recessive gene on the X chromosome which codes for superior spatial ability. Bearing in mind that sex-linked recessive conditions, such as color blindness, result in a preponderance of affected males; they concluded that such a theory could account for the good spatial ability found among their sample of disabled readers, the familial pattern of the disorder, and the frequently reported sex ratio of 3:1 affected males to females.

It is also entirely possible that selection bias favoring disabled readers with good spatial ability could also account for these results. For example, it is well-known that males tend to achieve higher mean scores on tests thought to measure spatial ability (see Wittig and Peterson, 1979 for a review). Although such significant mean differences between males and females account for only a small proportion of the total variance in spatial scores, even relatively small mean differences can generate disproportionate sex ratios favoring males at the upper end of the distribution scores. To illustrate this point, McGee (1982) has demonstrated how a $\underline{d}$ statistic may be calculated which will provide an index for expressing the magnitude of such sex differences by subtracting the mean scores of females from males, and by dividing by the SD of either group (assuming the SDs are equal). Using this statistic, a $\underline{d}$ score of .5 would result in an expected male to female sex ratio of approximately 3:1 at + 2 SD above the mean. Thus, an ascertainment bias favoring the selection of males might occur if reading-disabled subjects were selected either directly by requiring average or above scores on a spatial or nonverbal IQ measure, or indirectly by requiring an average full scale IQ which consists of a high performance score to offset a low verbal score.

In a previous report of these data from the Colorado Family Reading Study (Decker and DeFries, 1980), it was shown that a familial pattern of deficits for reading and the ability to process symbols rapidly was present among the parents and siblings of the reading-disabled children. However, no such familial pattern of deficits was apparent for spatial/reasoning. Therefore, it was concluded that any hereditary predisposition for reading disability could not be attributed to an inherited pattern of deficits in spatial/reasoning ability. However, the possibility that the unequal sex ratio of reading-disabled males to females might be associated with a selection bias for superior spatial ability, or that the inheritance of spatial

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* also known as developmental dyslexia or dyxlexia

ability might be sex-linked was not considered. Thus, this report will provide the first empirical test of the Symmes and Rapoport (1972) hypothesis, as well as a test for ascertainment bias which might favor reading-disabled males.

METHOD

The Family Study Design

Subjects. Children were referred to the study by personnel in the Boulder Valley and St. Vrain Valley School districts in Colorado. The criteria for the referral of these reading-disabled children (probands) were as follows: a reading achievement level of one-half of grade level expectancy; an IQ of 90 or above as measured by a standardized intelligence test; chronological age between 7.5 and 12 years; no known emotional, neurological, or behavioral disorders; no uncorrected visual acuity problems; normal auditory acuity; and residence with both biological parents.

Each reading-disabled proband was matched to a control child according to sex, age (within 6 months), school, and home neighborhood. The control children met all of the same criteria as the reading-disabled children, except that their reading level was equal to or greater than their current grade placement. This ascertainment and matching procedure resulted in 125 matched pairs of children (96 male pairs and 29 female pairs). In addition, parents and siblings (7.5 to 18 years of age) for both samples of readers were also tested resulting in a total sample size of 1,044 individuals. Typically, families for both samples of children were middle-class Caucasian, and English was the primary language spoken in the home.

Tests and procedures. An extensive battery of psychometric tests was individually administered to each family member by a trained examiner. From this battery, age-adjusted scores for the parents and children on eight tests which were administered to all subjects were selected for analysis (Table 1).

Table 1

Selected psychometric tests which were administered to all subjects.

Peabody Individual Achievement Test (PIAT)
Mathematics
Reading Recognition
Spelling
Nonverbal Culture Fair Intelligence Test (IPAT "g")
Primary Mental Abilities Test
Spatial Relations
Colorado Perceptual Speed Test: Rotatable Letters and Numbers
Wechsler Intelligence Scale for Children
Coding B

mean score than the control males. No significant effect was found for the sex by group interaction. Thus, there was no evidence for selection bias which favored reading-disabled male probands with above average spatial ability.

Results of the test for a recessive sex-linked major gene, which codes for superior spatial ability, failed to detect any familial pattern consistent with sex linkage in either the reading-disabled or control samples (see Table 2).

Table 2

Single-parent/single-child correlations for spatial/reasoning ability.

Expected order for a sex-linked trait:	Father-son <	mother-daughter <	mother-son =	father-daughter
Observed family Correlations[a]				
Reading-Disabled	.31 (115)	.29 (79)	.14 (115)	.48 (76)
Control	.27 (111)	.19 (68)	.18 (111)	.27 (68)

[a] Number of paired comparisons in parentheses.

Thus, the disproportionate sex ratio of affected males to females (3:1), and the familial pattern of reading deficits are not associated with sex-linked inheritance for spatial/reasoning ability, at least as measured by the test utilizing ordered parent-child correlations.

DISCUSSION

Results of this study demonstrate that although males tend to perform better than females on tasks requiring spatial/reasoning ability, there is no reason to believe that ascertainment bias favoring reading-disabled males with superior spatial ability could account for the 3:1 (male:female) sex ratio observed in our reading-disabled sample.

Tests for sex-linkage failed to confirm the Symmes and Rapoport (1972) hypothesis. Although both reading disability and spatial/reasoning are thought to be influenced by genetic factors, it seems unlikely that the two traits are linked on the X chromosome. Rather, it is more reasonable to speculate that spatial/reasoning ability is less influenced by factors which are known to be associated with poor reading such as verbal ability. However, it is important to note that reading disability may be a heterogeneous disorder with etiologically distinct subtypes. If that is found to be the case, an X-linked subtype should not be ruled out.

With regard to familial patterns of spatial ability, spatial/reasoning scores obtained from the biological siblings and parents of the reading-disabled children confirmed a familial pattern of competence but not of superiority when compared to the respective members of the control families. This stands in marked contrast to the familial pattern of deficits previously reported for reading and symbolic processing speed (Decker and DeFries, 1980). Thus, a familial pattern of reading deficits does not appear to be etiologically related to spatial/reasoning ability.

These tests were intercorrelated and then subjected to principal component analysis with Varimax rotation. Three readily interpretable ability dimensions thought to measure reading, spatial/reasoning and coding/speed were identified. A composite Z-score for each of the three ability dimensions was calculated for each subject. For this report, only results based upon the spatial/reasoning composite measure will be considered. This dimension was primarily defined by the PIAT mathematics subtest factor loading of .58, the IPAT "g" loading of .76, and the PMA spatial relations subtest loading of .85. The loadings for each of the remaining five tests were .30 or less. Since the two tests which showed the highest factor loadings are thought to measure spatial visualization, and to some extent nonverbal IQ or reasoning ability, the spatial/reasoning interpretation was thought to be appropriate. A complete discussion of these procedures may be found in Decker and DeFries (1980).

In order to test for selection bias that might favor males with superior spatial skills, a hierarchical multiple regression analysis (Cohen and Cohen, 1975) was calculated. The proband's spatial/reasoning score is expressed as a function of sex (male vs. female), group membership (affected vs. control), and the sex by group interaction. This interaction is represented by the product of sex and group from which the main effects have been partialed out. Thus, sex was entered as step 1, group step 2, and finally their interaction as step 3. A significant two-way interaction between sex and group indicates a conditional relationship between the proband's spatial/reasoning score and the variables of sex and group. Therefore, if ascertainment bias is present, a significant interaction effect should be apparent.

To test for the presence of a sex-linked major gene, ordered correlations between parental and offspring scores may be utilized (Vandenberg and Kuse, 1979). This occurs because, in addition to the 22 pairs of autosomes, females have two X chromosomes, whereas males have only one X chromosome. This means that a female must carry the recessive allele on each of her X chromosomes in order to express the characteristic of interest. However, males need only the one recessive gene on their X chromosome to manifest the trait. Thus, father-son correlations for a sex-linked recessive condition should be near zero, while the other expected pattern of parent-child correlations are as follows:

$$\text{Father-son} < \text{Mother-daughter} < \text{Mother-son} = \text{Father-daughter}$$

Using the spatial/reasoning measure which had all quadratic and linear age effects removed in order to facilitate parent-child correlations, single-parent, single-child correlations were calculated to test for a sex-linked recessive gene which codes for good spatial ability.

RESULTS

When the mean spatial/reasoning Z-scores for the reading-disabled female probands ($\bar{X} = -.50$), and their matched controls ($\bar{X} = -.39$) are compared to the mean scores for the reading-disabled male probands ($\bar{X} = -.14$) and their matched controls ($\bar{X} = .41$), it is clear that the females perform less well than the males regardless of group membership. Results from the hierarchical multiple regression revealed a significant sex effect ($p < .01$) which accounted for only 6% of the total variance, while the significant ($p < .01$) group effect accounted for 5%. It should also be noted that the reading-disabled males demonstrated a lower

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